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ESTIMATING THE HEIGHT OF CATTLE FROM PHOTOGRAPHS BY MEASUREMENT OF NECK CHAINS

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ESTIMATING THE HEIGHT OF CATTLE FROM PHOTOGRAPHS BY MEASUREMENT OF NECK CHAINS

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In selection programs for breeding animals, as in progeny testing of sires, in growth studies, and in screening operations, certain measurements of the animal may be desired. It is often easier to obtain estimates of these from photographs of the animal rather than to actually measure the animal with calipers or tape. This is particularly true if the animals are on pasture at a distance from facilities for measuring them or are difficult to handle. At the Agricultural Research Center, Beltsville, Maryland, an attempt has been made to determine how accurate such estimates might be for the height of cattle at the withers.

Materials and Methods

Two groups of animals were used. The first consisted of 34 two-year-old steers, of which 29 were Milking Shorthorns and 5 were Herefords. The second group was of 20 steers 22 months old. Ten of the 20 steers were Milking Shorthorns and 10 were Herefords. One picture was taken of each of the animals in the first group and two pictures of each of the animals in the second group. An attempt was made to have the pictures show a full side view of the animals standing in a normal position. Pictures were taken from a distance of approximately 15 feet by professional photographers using 4 x 5 Speed Graphic cameras. The images of the animals varied from approximately 3 centimeters to 7 centimeters in height. Pictures were taken with the animals loose in the barnyard. None of the steers had been handled much or taught to pose. Pictures of two of the animals are shown in figure 1. Pictures of animals in group I were taken by one photographer while those of animals in group II were taken by another photographer.

Each animal wore a twisted link cattle chain around its neck. When new, this chain contained nine links per foot of chain. Since the animals were not very old and all the animals had worn their chains about the same length of time, wear on the chains was slight and about the same on all chains.

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To estimate the height of the animal from the picture, the length of 4 links of chain lying flat on the side of the neck was measured in the picture and the height of the animal at the withers was measured in the picture. Since it can be assumed that the height of the animal in the picture bears the same relation to the real height as the length of 4 links of chain in the picture bears to the real length of 4 links of chain, one can estimate the height from the following formula:

$$\text{Estimated height} = \frac{\text{height in picture x real length of 4 links of chain}}{\text{length of 4 links chain in picture}}$$

if one knows the real length of 4 links of chain.

The average length of 4 links of chain was 14.245 centimeters. This was obtained from two sets of 4 links each of 15 neck chains which had been worn about the same length of time as those on the cattle studied. The length of 9 links of these chains ranged from 12 1/8 inches to 12 5/8 inches and averaged 12 1/4 inches. Measurements were taken from the outside edge of the end links when the chain was pulled tight.

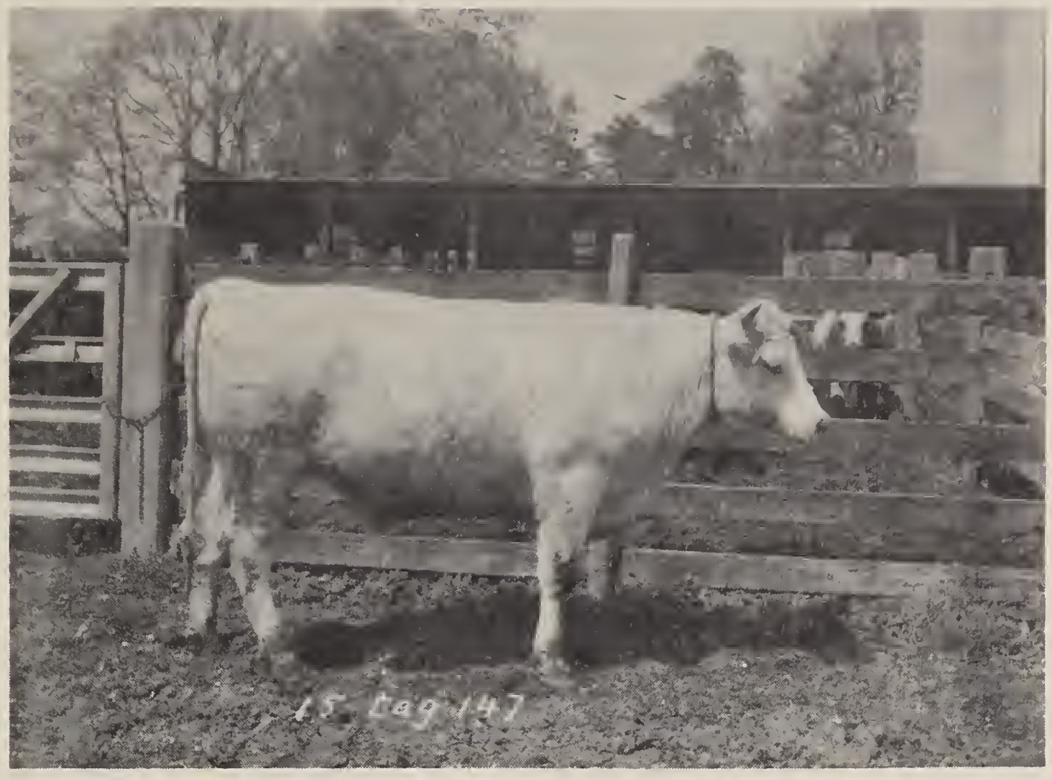
In a preliminary study, results from using 4 links of chain to estimate the height appeared to give as good, if not better, results than using 6 links of chain. It was often difficult to measure 6 links of chain without getting a noticeable distortion due to the chain curving around the neck.

The animals were all measured for height at withers with a measuring standard either the same day or the day after the pictures were taken. These measurements were all taken by one man but were taken three times by him and the average of his three measurements was used to compare with the estimated height from pictures. This has been called the measured height of the animal in the study to differentiate it from the estimated height obtained from the picture.

Not all of the pictures were sharp and in some cases the animals were not standing in the best positions. However, it is believed they represent about what one could expect to obtain in another sample of pictures.

A focusing magnifier made by Bausch and Lomb Optical Company,** Rochester, N. Y., was used in measuring the pictures. This magnifier magnified 6.5 times and contained a scale 20 millimeters long divided into tenths of millimeters. A photographic enlarger and a slide projector were also used but they did not give as sharp an image as the magnifier. This does not mean that all magnifiers would be superior to all photographic enlargers or slide projectors. The magnifier had the advantage that it did not get hot. In using the magnifier a contact print of the picture was placed on the glass top of a light box so that the light came through the picture from underneath.

**Mention of this firm does not constitute endorsement of its products by the U. S. Department of Agriculture over similar products not mentioned.



Milking Shorthorn steer No. 15, tag 147. One of the two steers where height was estimated most accurately from the picture. Estimated height 139.8 cm.; measured height 139.7

Milking Shorthorn steer No. 272, tag 444. One of the two pictures of the steer whose height was least accurately estimated from the pictures. Estimated height 159.5 cm.; measured height 130.7 cm. The fact that this steer does not stand quite square with the camera and the key ring connecting the chain lies close to the middle of his neck may be the contributing difficulty in getting an accurate estimate.

Figure 1

Each picture was independently measured twice by each of three different observers in order to obtain estimates of the accuracy with which measurements could be repeated by the same observer and by different observers.

Data were studied by methods for analysis of variance (Snedecor 1956) and correlations between the estimated height and the measured height were obtained by the method of path coefficients (Wright 1921 and 1934).

Results and Discussion

Variances were calculated from the expected composition of the mean squares for the studies of the 34 steers and the 20 steers (tables 1 and 2).

Table 1. Analysis of Variance for Group of 34 Steers

Source of Variation	d.f.	Mean Squares	Composition of mean squares
Between animals	33	475.63**	$\sigma_e^2 + 2(\sigma_{op:a}^2 + \sigma_{oa}^2) + 6(\sigma_{p:a}^2 + \sigma_a^2)$
Between observers	2	577.96**	$\sigma_e^2 + 2(\sigma_{op:a}^2 + \sigma_{oa}^2) + 68\ \sigma_o^2$
Observers x animals	66	36.86**	$\sigma_e^2 + 2(\sigma_{op:a}^2 + \sigma_{oa}^2)$
Error	102	18.37	σ_e^2
Total	203		

$\hat{\sigma}_e^2 = 18.37, (\hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2) = 9.24, \hat{\sigma}_o^2 = 7.96, (\sigma_{p:a}^2 + \hat{\sigma}_a^2) = 73.13$

** highly significant

These show some differences in the two groups. Since only one picture per steer was measured in the case of the 34 steers, it was not possible to separate out picture effects in that analysis. The error variance was considerably larger in the study with the 34 steers than in that of the 20 steers. This was due in part to the pictures in the two studies being different in size. Thus the mean length of 4 links of chain in the pictures of the 34 steers was 3.75 millimeters while that for the 20 steers was 5.78 millimeters. The error variance of measuring the 4 links of chain in the pictures of the 34 steers was .021 millimeters while in the pictures of the 20 steers it was .011 millimeters. The variance between animals was greater in the group of 20 steers than in the group of 34 steers as might be expected from differences in height due to breed.

Correlations were calculated from the variances for the 20 steers as being the best estimates available although it was realized that the correlations would be higher than if a more uniform group of steers was used. These correlations were first between measurements of the same

Table 2. Analysis of Variance for Group of 20 Steers

Source of Variation	d.f.	Mean Squares	Composition of mean squares
Between animals	19	1503.71**	$\sigma_e^2 + 2\ \sigma_{op:a}^2 + 4\ \sigma_{oa}^2 + 6\ \sigma_{p:a}^2 + 12\ \sigma_a^2$
Between observers	2	936.30**	$\sigma_e^2 + 2\ \sigma_{op:a}^2 + 4\ \sigma_{oa}^2 + 80\ \sigma_o^2$
Pictures within animals	20	161.03**	$\sigma_e^2 + 2\ \sigma_{op:a}^2 + 6\ \sigma_{p:a}^2$
Observers x animals	38	51.86	$\sigma_e^2 + 2\ \sigma_{op:a}^2 + 4\ \sigma_{oa}^2$
Observer x pictures within animals	40	40.27**	$\sigma_e^2 + 2\ \sigma_{op:a}^2$
Error	120	6.08	σ_e^2

$\hat{\sigma}_e^2 = 6.08$, $\hat{\sigma}_{op:a}^2 = 17.20$, $\hat{\sigma}_{oa}^2 = 2.90$, $\hat{\sigma}_{p:a}^2 = 20.13$, $\hat{\sigma}_a^2 = 110.92$, $\hat{\sigma}_o^2 = 11.06$

** highly significant

observer on the same picture $\left(r_1 = \dfrac{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_e^2} = .961\right)$

and of the same observer on different pictures of the same animal

$\left(r_2 = \dfrac{\hat{\sigma}_a^2 + \hat{\sigma}_{oa}^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_e^2} = .724\right)$.

Then correlations were calculated between different observers on the same picture $\left(r_3 = \dfrac{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_o^2 + \hat{\sigma}_e^2} = .779\right)$

and between different observers on different pictures of the same animal

$\left(r_4 = \dfrac{\hat{\sigma}_a^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_o^2 + \hat{\sigma}_e^2} = .659\right)$.

All of these correlations are on a single measurement basis.

To determine the correlation between the heights of the animals estimated from the pictures and the heights obtained from measurements

with a measuring standard the variance was determined between and within measurement, observer and picture subclasses for the group of 20 steers. The variance within the subclasses was divided into that between methods of measurement, between animals and between methods x animals interaction, table 3. The correlation was

$$r_5 = \frac{\hat{\sigma}_a^2}{\hat{\sigma}_a^2 + (\hat{\sigma}_{om'}^2 + \hat{\sigma}_{m'}^2) + \hat{\sigma}_e^2} = .539 .$$

Table 3. Analysis of Variance for Estimated and Measured Heights of the Animals in the Group of 20 steers.

Source of Variation	d.f.	Mean Squares	Composition of Mean Squares
Between measurement, observer, picture subclasses (MOP)	11	90.10	
Between methods(M':MOP)	12	738.76**	$\sigma_e^2 + 20(\sigma_{om'}^2 + \sigma_{m'}^2)$
Between animals(A:MOP)	228	201.87**	$\sigma_e^2 + 2\,\sigma_a^2$
Methods x animals (M'A:MOP)	228	35.79	σ_e^2

$\hat{\sigma}_e^2 = 35.79$, $\hat{\sigma}_a^2 = 83.04$, $(\hat{\sigma}_{om'}^2 + \hat{\sigma}_{m'}^2) = 35.14$

** highly significant

Correlations r_3, r_4 and r_5 were also calculated on an adjusted basis assuming in the case of r_3 and r_4 that observer differences were removed and in the case of r_5 that methods of measurement and observer differences were removed. The values for these adjusted coefficients were:

$$r_3 \text{ adj.} = \frac{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_e^2} = .833$$

$$r_4 \text{ adj.} = \frac{\hat{\sigma}_a^2}{\hat{\sigma}_a^2 + \hat{\sigma}_{p:a}^2 + \hat{\sigma}_{op:a}^2 + \hat{\sigma}_{oa}^2 + \hat{\sigma}_e^2} = .705$$

$$r_5 \text{ adj.} = \frac{\hat{\sigma}_a^2}{\hat{\sigma}_a^2 + \hat{\sigma}_e^2} = .699 \ .$$

If one wishes to predict the correlations that would be obtained between heights estimated from pictures and those from measuring the animals with a standard with different numbers of measurements per observer, different numbers of observers and different numbers of pictures per animal, one may do so using the following formula:

$$r_6 = \sqrt{\frac{n\,k\,q}{1+(n-1)r_1 + (k-1)nr_3 + (q-1)\left[r_2 + (k-1)r_4\right]\left[1+(n-1)r_1\right]}} \times r_5$$

in which n = the number of measurements, k = the number of observers and q = the number of pictures. These predicted corrleations are given in table 4.

Differences between observers were highly significant as judged by the size of the mean squares (578 and 936) between observers compared to the error terms (37 and 52) in the groups of 34 and 20 steers, respectively. Observers were apparently consistent when they measured the same picture twice as indicated by the correlation between measurements by the same observer on the same picture (r_1 = .961). However, different observers did not measure the same picture in the same manner (r_3 = .779). Although r_3 is a fairly high correlation, it is not nearly as high as r_1. Increasing the number of pictures of the animal would give slightly more increase in accuracy than increasing the number of observers (r_2 = .724 as compared with r_3 = .779) and considerably more accuracy than increasing the number of measurements per observer on the same picture.

It was not considered advisable to predict the correlation between the estimated height and the measured height with more than four observers, three pictures per animal and three measurements per observer per picture. This was one more observer, one more picture and one more measurement than was actually used. The size of the sample is not very large, with a different sample, one might get somewhat different results.

The expected intra-class correlation between the estimated height and the measured height is increased considerably by adjusting for the average differences between the methods and the average differences between observers. This was done in calculating the adjusted correlation in table 4 by omitting the variances due to observers, methods, and observer x method interaction from the calculation of the correlation. This assumes that a perfect adjustment can be made.

Table 4. Correlations between estimated height and measured height with different numbers of measurements per observer (n) different numbers of observers (k) and different numbers of pictures per animal (q).

No. of Measurements	No. of Observers	No. of Pictures	Unadjusted r	Adjusted r
1	1	1	.539	.699
1	1	2	.581	.753
1	1	3	.597	.774
1	2	1	.571	.730
1	2	2	.604	.774
1	2	3	.635	.791
1	3	1	.584	.742
1	3	2	.616	.781
1	3	3	.627	.796
1	4	1	.590	.770
1	4	2	.620	.785
1	4	3	.632	.800
2	1	1	.544	.706
2	1	2	.586	.761
2	1	3	.603	.781
2	2	1	.575	.734
2	2	2	.611	.779
2	2	3	.624	.797
2	3	1	.586	.744
2	3	2	.619	.786
2	3	3	.632	.802
2	4	1	.592	.749
2	4	2	.624	.790
2	4	3	.636	.805
3	1	1	.546	.708
3	1	2	.588	.763
3	1	3	.604	.784
3	2	1	.576	.735
3	2	2	.612	.781
3	2	3	.626	.799
3	3	1	.587	.745
3	3	2	.621	.788
3	3	3	.634	.805
3	4	1	.592	.750
3	4	2	.625	.791
3	4	3	.638	.807

In the group of 34 steers the average estimated height (204 estimates) was 3.6 centimeters taller than the measured height. In the group of 20 steers the average estimated height based on 240 estimates was 8.1 centimeters taller than the measured height. The estimated height was larger than the measured height for 23 of the group of 34 steers and for 19 of the

group of 20 steers. Differences ranged from -6.1 to +15.4 centimeters and from -1.5 to +20.5 centimeters in the groups of 34 and 20 steers, respectively. These differences were highly significant for the first group ($P < .01$) and significant ($P < .05$) for the second group with standard deviations of 5.6 and 6.3, respectively. Thirty-four percent of the variance component ascribed to both animals and pictures within animals in table 1 and 22 percent of the variance ascribed only to animals in table 2 was found to be due to biases associated with animals (probably due to the way the pictures were taken).

Differences between observers were generally consistent. Observers numbers 1 and 3 in most cases measured the animals taller than observer number 2. In the group of 20 steers observer number 1 measured most of the steers taller than observer number 3 but in the group of 34 steers the reverse was true although for only 20 steers out of 34. The average differences in the estimated heights as determined by different observers ranged from 0.7 cm. to 5.3 cm. and from 1.8 cm. to 6.6 cm. in the groups of 34 steers and 20 steers, respectively.

When the animals were measured with the measuring standard, the horizontal bar was pressed down hard on the back compressing the hair, skin and flesh to a noticeable extent. This was done because it gave more repeatable measurements than "loose" measurements gave. With the pictures, the observers tried to make some allowance for the hair standing up on the back but it was not possible to take as "tight" a measurement as was taken with the measuring standard. This probably is responsible for some of the average difference between the methods.

The height of the animal in the picture was measured from the bottom of his near front foot, or from where it was thought the bottom of his foot was in case it could not be clearly seen, to the top of the withers. This also may have contributed to over-estimating the height from the picture. Average differences in the measurements by different observers using the same picture are not easily explained except for differences in judgment with respect to where a measurement was to begin or end. Since the known measurement (the length of 4 links of chain) was relatively small compared to the height of the animal, even small differences in measuring the chain in the picture made considerable difference in estimating the height of the animal. An estimated height based on the average height measured from both front feet, where both can be seen, and getting larger pictures that are clear with a minimum of distortion might help some. The photographer should be careful to have the animal stand at right angles to the camera, with feet squarely under him. The pictures should be clear, as large as possible, and with a minimum of distortion. This is indicated by the percent of variance among animals due to biases. Although the observers each had some preliminary practice, further training would probably help reduce their differences. An improvement in the technique of measuring the 4 links of chain in the picture might do as much as anything to improve the accuracy. This would probably

require a greater magnification of the picture and the use of a scale that could be read easily to less than a tenth of a millimeter.

This method of measurement is of sufficient accuracy, particularly with adjusted data, to be useful where it will be applied to groups of animals, such as progeny groups in a sire testing program or in a screening operation to select animals that should be actually measured with a standard. If one needs measurements on animals which are difficult to handle it is definitely superior to trying to measure with a standard. At the Agricultural Research Center, Beltsville, Md., it was used to advantage to get measurements of animals on pasture where it would have been impractical to use ordinary methods.

Summary

The heights of two groups of 34 and 20 steers, respectively, were estimated from individual pictures showing the full side view of each animal and taken from a distance of approximately 15 feet. One picture of each of the 34 steers and two pictures of each of the 20 steers were taken. Each animal wore a neck chain of known length. The height of the animal was estimated by assuming that the height of the animal measured in the picture had the same relationship to the real height as the length of 4 links of chain in the picture had to the real length of 4 links of chain. Each picture was measured twice by each of 3 observers. Each steer was measured with a measuring standard soon after his picture was taken. Estimates of the variance due to animals (110.92), observers (11.06), observer x animal interaction (2.90), picture within animal interaction (20.13), observer x picture within animal interaction (17.20) and error (6.08) were obtained. From these values correlations were calculated between measurements of the same observer on the same picture (.96), between measurements of the same observer on different pictures of the same animal (.72), between different observers on the same picture (.78) and between different observers on different pictures of the same animal (.66). Correlations obtained between the estimated heights from the pictures and the measured heights using a measuring standard with from 1 to 3 measurements per animal varied from .539 to .638 when unadjusted for mean differences between methods and observers and from .699 to .807 when adjusted for these differences. Increasing the number of pictures had a slightly greater effect on the size of the correlation than increasing the number of observers while increasing the number of measurements per observer had considerably less effect. Use of the method is discussed.